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Research Article

Management effectiveness of Nature Conservation Units in southern Brazil

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Abstract

The implementation of protected areas, in particular, nature Conservation Units (CUs), is a conservation strategy recognised worldwide. However, these territories require efficient management to achieve their conservation goals. When the management of CUs is deficient, it results in damage to their own goals, affecting biodiversity and ecological processes, as well as causing social and economic impacts. In this context, we evaluated the management effectiveness of 11 integral Conservation Units of nature in the State of Rio Grande do Sul, southern Brazil, through interviews, visits to these CUs and a review of their official documents. For this analysis, we used the adapted method of Effectiveness of Management of Protected Areas (EMAP), which was analysed using a Likert scale with five levels, eight scopes, 73 indicators and 65 evaluation scenarios. Ninety-one percent of the CUs assessed in southern Brazil by the EMAP method oscillated from average to very unsatisfactory efficacy and low management effectiveness: 18% of the CUs had a very unsatisfactory quality of management, 37% unsatisfactory, 36% average and only 9% high or satisfactory. Moreover, the CUs did not fulfil the main objectives for which they were created. In this context, we recommended a series of actions to be applied for CU improvement, such as the adoption of a quali-quantitative evaluation model for the units, through a mathematical model; increase in staff; training teams and managers; improvement of CU infrastructure and inputs; regular budget allocation; land regularisation, implementation of consultative councils and urgent review of management plans.

Key words: biodiversity, conservation, effectiveness of management of Protected Areas, Likert scale, management plan, Protected Areas, Rio Grande do Sul

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Introduction

The Protected Areas (PAs), as they are internationally recognised or nature Conservation Units (CUs), are special territories that are fundamental for the conservation of biodiversity (Tossulino et al. 2006). PAs represent major

management efforts to reduce anthropogenic pressures in natural areas (Schulze et al. 2018) and currently one-sixth of the world's land surface is within a Protected Area (Geldmann et al. 2019). Conservation units are important for the economy since they provide environmental services and are fundamental areas for scientific research studies, environmental education practices and sustainable tourism, being essential for maintaining all life forms, including humans. In Brazil, PAs for Integral Protection and Sustainable Use are found in all Biomes: 42.2% in the Amazon, 3% in the Caatinga, 6.8% in the Cerrado, 0.3% in the Pantanal, 4.7% in the Atlantic Forest, 0.2% Pampa and 37.8% in Marine and Coastal environments (Sistema Nacional de Informações Florestais 2021).

The State of Rio Grande do Sul, southern Brazil, shows a great diversity of native fauna and flora distributed in two important Brazilian biomes: the Atlantic Forest and the Pampa, the latter also known as Campos Sulinos, as well as important transition zones between the two biomes.

The Atlantic Forest consists of three basic formations: the dense and open rainforest, mixed rainforest and seasonal and semi-deciduous forest, besides abundant transition zones (Galindo-Leal and Câmara 2005) with varied forest formations, such as natural fields, restingas (dried coastal biome), mangroves and other local characteristic vegetation formations (Oliveira and Engel 2017). Native species of both fauna and flora in this biome are highly threatened, according to official lists, as a consequence of habitat fragmentation, hunting and fauna illegal trade, as well as human occupations and local economic exploitation, according to State Decrees No. 53,902/2018 and State Decree No. 54,171 /2018.

The Pampa Biome in Rio Grande do Sul State is perhaps more impacted than the Atlantic Forest due to a lack of knowledge and its very specific ecological characteristics related to the southwest and south regions of Brazil (Oliveira and Engel 2017). This biome corresponds to 63% of the State territory and 2.07% of the Brazilian territory. It is the least representative biome in the National System of Conservation Units (SNUC), with 0.4% of the Brazilian territory protected in the form of CUs (Ministério do Meio Ambiente 2021).

In order to preserve significant portions of each Brazilian biome, states and municipalities must be able to create and manage PAs in their various categories, especially those belonging to the Integral Protection group, which allows the connection between natural areas to fulfil the role in ecosystems conservation, ecological processes and species. The creation of specially protected areas has been considered one of the best strategies for biodiversity conservation and represents a necessary action to deal with increasing human occupations and the simplification of natural resources in a predatory way (Bensusan 2006).

However, these actions have not been efficient in protecting biodiversity in many countries worldwide, as many PAs continue to face severe threats and anthropogenic pressures, as well as deficiencies in the management processes and in fulfilling the purposes for which they were created (Faria 2007; Laurance et al. 2012; Geldmann et al. 2013; Geldmann et al. 2021). Additionally, it is worth highlighting that PAs present a series of historical conflicts, such as land regularisation, lack of employees and basic infrastructure and even lack of inspection.

All these issues are often aggravated by the absence of Management Plans, which, after their creation, become the primary official document of norms, rules and programmes for CU management (Pontes and Mello 2013). Other

problems related to PA management are the difficulties faced by managers, which pervade environmental problems, highlighting economic and social aspects, amongst others, such as those related to political and governmental agendas (Brito 2008). Given these conflicts, there is a need to prioritise continuous management actions for PA conservation to effectively fulfil its goals (Faria 2006).

The CUs, according to Federal Law 9.985/2000, National System of Nature Conservation Units (SNCU), are protected territorial spaces (= Protected Areas (PA)), comprising environmental resources, including jurisdictional waters of relevant natural characteristics, in three government spheres: Federal, State and Municipal. The CUs have conservation goals and defined limits, which are governed by their respective administration, applying guarantees to protect these areas (Brasil 2000). In this sense, it is essential to assess the effectiveness of CUs in protecting biodiversity and whether they are legitimately mitigating anthropogenic pressures and preserving ecological processes (Geldmann et al. 2019).

The importance of establishing an evaluation system for PA management lies in fully achieving its management and conservation goals. From the 1990s on, some studies were carried out to assess the effectiveness and the management of protected areas, based on different systematic methodologies, specifically developed to meet the needs of different regions and habitats, according to the reality of each PA (Faria 1993, 1995, 1997, 2004, 2006, 2007; Izurieta 1997; Mesquita et al. 2000; Parrish et al. 2003; Hockings et al. 2003, 2006; Medeiros and Pereira 2011; Schacht and Rocha 2016; Schulze et al. 2018; Geldmann et al. 2019, 2021).

These methods are qualitative and quantitative and were developed as instruments to “measure” the management effectiveness in a CU to enable improvement in management processes and ensure the effectiveness and success in these areas (Cifuentes et al. 2000). These studies have indicated how the management process is conducted and how the achieved results were consistent with the CU scenario. Based on these results, it would be possible to suggest practices, regulations and monitoring in a systematic way that promote improvements and an increase in efficiency within the PA management processes (Chape et al. 2008).

The assessment of management effectiveness includes three main components: (1) design issues related to individual sites and the protected area system, (2) adequacy of management systems and processes and (3) delivery of protected area objectives (Hockings 2000). A generic approach of the World Commission on Protected Areas (WCPA) proposed evaluations of 27 methodologies, which identified two types of data: quantitative derived from monitoring and qualitative derived from scoring by managers (Hockings et al. 2003).

Overall, all the methods to conduct the analyses and evaluation of the effectiveness of management of protected areas (PAs) are based on analytical-descriptive studies because the descriptors of indicators have numerical scales for the qualification and quantification of the level of effectiveness of management, such as the Likert scale (Cifuentes et al. 2000; Azevedo et al. 2016). This scale applies closed-ended questions with five possible answers and can be used for questions associated with more nuanced possible responses because it measures the level of effectiveness of management for each issue.

The response options range from 0 as ineffective to 4 as extremely effective in relation to each question (Cifuentes et al. 2000) (see Table 2 and Suppl. material 1 for details). Moreover, these methods can use averages and percentages to quantify the results. All the ways to present the results by each method can be adapted to their respective indicators and goals.

The WCPA has developed the Rapid Assessment and Priority of Protected Area Management (RAPPAM) methodology, which has been widely applied by the World Wildlife Fund (WWF) in 150 countries (Ervin 2003), this being one of the most used methods to assess management effectiveness in the world (Hockings et al. 2006; ICMBio 2011).

On the other hand, the method of greatest projection and application in Latin America in the 2000s was the Measurement of the Effectiveness of the Management of Protected Areas (EMAP) (from the Spanish: "Medición de la Efectividad del Manejo de Areas Protegidas" – Cifuentes et al. (2000)). Another method is Management Excellence (MEG), which considers learning and organisation tools: Plan, Do, Execute, Check, Action (PDCA) (Rodrigues 2014). According to Hockings et al. (2003), the RAPPAM and EMAP methods are similar, as they comply with six management principles or components in evaluating effectiveness: Context, Inputs, Planning, Process, Outputs, Outcomes.

Another method of evaluating the effectiveness of PA management is the Management Effectiveness Tracking Tool (METT), which was developed in partnership between WWF and the World Bank and was applied in eight countries in Europe, Asia, Africa and Latin America. This method allows identifying the needs and restrictions of PAs, prioritising the development of actions to improve management effectiveness (Stolton et al. 2007; Júnior and Agra Filho 2014).

The System of Social and Environmental Indicators of Conservation Units (SSEICU, in Portuguese SISUC) was created in 2008 and is a methodology for evaluating the management of PAs that uses socio-environmental indicators, having as central themes economy, sociocultural, environment and management (Marinelli 2011) and was initially used in northern Brazil (Silva 2016).

The method developed by the Chico Mendes Institute for Biodiversity Conservation (ICMBio), named the Management Analysis and Monitoring System (SAMGE), is based on management panels and spatialisation of information. It aims to evaluate compliance with public policy for biodiversity conservation, through the PAs, resulting in a diagnosis of a set of information that enables the construction of indicators of effectiveness. This is a tool of fast application with immediate results applied annually.

In 2017, the "Green List of Protected and Conserved Areas" programme was proposed by The International Union for Conservation of Nature (IUCN) as an evaluation method that combines environmental and socioeconomic issues, integrating the 17 Sustainable Development Goals (SDGs) of the UN 2030 agenda. However, according to the Expert Assessment Groups Green List' (EAGLs), the Green List method is still an experimental protocol for the Brazilian territory and maybe with unattainable criteria for the local scenario, with no validation until this moment. The design for the Brazilian reality is currently in progress and only for some Amazonian areas as candidates for this certification in 2023.

Despite the existence of several methodologies to measure the effectiveness of PA management, no evaluation was made with CUs in southern Brazil. Thus, in this study, we aimed to evaluate the effectiveness of management of Full

Protection PAs in the state of Rio Grande do Sul using the adapted methodology EMAP (Cifuentes et al. 2000). Moreover, this method was chosen because it was already applied in other CUs from Brazil, which allow us to compare the results with the present study and it was adapted to different realities in protected areas, allowing the construction of matrices of scenarios. Based on the results, potential improvement strategies were discussed to achieve greater effectiveness in the processes of biodiversity management and conservation, in the long term, to fulfil the objectives and legal purposes of this territory.

Methods

Study area: assessed Conservation Units

In this study, 11 of the 23 CUs existing in Rio Grande do Sul, southern Brazil (Secretaria Estadual do Meio Ambiente e Infraestrutura 2021) were evaluated (Fig. 1) (Table 1). They are all terrestrial PAs, but with different management categories: eight State Parks (Itapuã, Espigão Alto, Itapeva, Delta do Jacuí, Espinilho, Ibitiriá, Tainhas and Turvo), one Biological Reserve (Serra Geral Biological Reserve), one Ecological Station (Aratinga Ecological Station) and one Wildlife Refuge (Wildlife Refuge of Banhado dos Pachecos). The criteria to select these CUs were: being a territory of a full protection area and having a management plan (official technical management document, according to Federal Law 9.985/2000) in the Biomes of Atlantic Forest and Pampa. The CUs studied are located in different municipalities and were concentrated in the northern and north-eastern parts of the State (Fig. 1).

Data sampling, indicators and analysis

Data were sampled through review and analysis of the Management Plans, other official documents of the CUs, as well as through the application of questionnaires during face-to-face interviews with managers in the CUs. In general, the visits to the CUs to conduct the interviews with their respective managers lasted approximately two days and were carried out between March and July 2022. To assess the management effectiveness and processes of these 11 CUs, an adaptation of the method known as Measurement of the Effectiveness of the Management of Protected Areas (EMAP) proposed by Cifuentes et al. (2000) of a quali-quantitative nature was used, whose development was based on the original principles of the ISO 10004 standard, dedicated to evaluating the quality of services offered by public and private companies.

In this adaptation, eight scopes were analysed, which are the indicators with the highest hierarchy, 73 indicators with evaluation parameters and/or scenarios measured using quantitative numerical scales with five assessment levels (Likert 1932) (see details of the questionnaire with scopes, indicators and scenarios in Suppl. material 1). The scopes, selected for this study with the EMAP method, received numerical scores, based on the Likert scale, with five levels between 0 and 4 (Likert 1932) (Table 2), to qualify the evaluation of CUs management effectiveness (Faria 2004). For example, an indicator of CU size will receive a score of 4 points (corresponding to the highest standard) when the CU has around 90% of its total surface in optimal state of conservation and zero

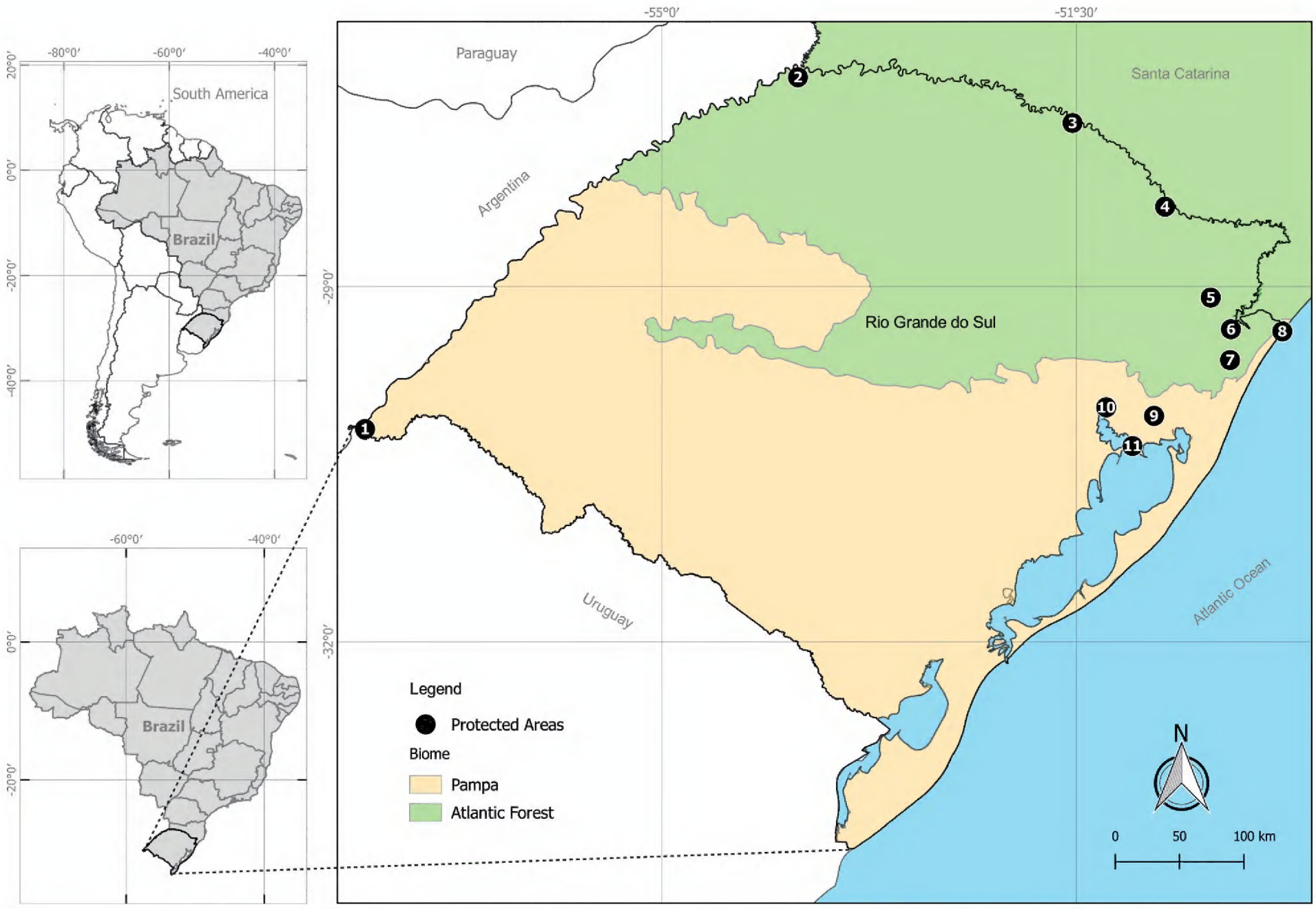

Figure 1. Distribution by Biome of the 11 Conservation Units (CUs) surveyed in Rio Grande do Sul, southern Brazil. 1. Aratinga Ecological Station; 2. Serra Geral Biological Reserve; 3. Tainhas State Park; 4. Ibitiriá State Park; 5. Espigão Alto State Park; 6. Turvo State Park; 7. Itapeva State Park; 8. Banhado dos Pachecos Wildlife Refuge; 9. Itapuã State Park; 10. Delta do Jacuí State Park; 11. Espinilho State Park.

points (corresponding to the lowest standard) when the CU has less than 35%. The method was adapted to the reality of the management categories, contemplating a set of compatible indicators, but keeping EMAP's fundamentals, considering the purposes of the protected areas of the 21st century, which allow the achievement of lasting conservation results in the management of CUs.

In this context, this scale confers different quality standards (scenarios) to the indicators, being 0, the lowest value referring to the much lower standard of effectiveness, 1 still a low standard, 2 a median standard, 3 a high standard and 4 the highest value and considered a standard of excellence (Table 2).

The qualification of Management Effectiveness (EFG) occurs through comparisons of the total achieved (TA), which is the sum of the achieved scores, from the indicators' analysis and the optimal total (TA), which consists of the sum of the highest scores obtained (100%). The resulting percentages are related to the scale, which qualifies the standard considered for management quality. Moreover, each CU was briefly described to explain their strengths and weaknesses and present suggestions.

We performed ordination analyses to describe the main trends of variation between CUs in the multidimensional space of the scopes and indicators. We used the interviews of managers from the 11 CUs as our sampling units and

the 73 indicators as variables. For a more general view, a data matrix of the 11 CUs described by the eight scopes (in Likert scale) was submitted to Principal Component Analysis (PCA), based on the Pearson correlation matrix between the RAW variables (scopes). The Pearson correlation matrix, used in PCA, is equivalent to a Covariance-Covariance matrix with data centred and normalised within variables (i.e. scaled). Then, a randomisation test was used to evaluate the significance of the patterns evidenced in the first three ordination axes, considering the null hypothesis that the pattern expressed by the axis (or axes) is not different from that expected at random, for a tolerance threshold of 10% (Pillar 1999).

For a more detailed view, the same ordination procedure was performed with a Randomisation Test, but for a data matrix of the 11 CUs described by 43 indicators (in the Likert scale; the political/ institutional legal indicator had the same value for all CUs, being disregarded in this analysis). The axes considered significant in the ordinations were then interpreted. Ordination analyses and Randomisation Tests were performed in MULTIV v. 3.85b (Pillar 2006).

Table 1. Information about the nature Conservation Units (CUs) of full protection in southern Brazil, analysed between March and July 2022.

Conservation Unit	Creation Decree	Area (ha)	Biome	Municipality
Delta do Jacuí State Park	Decree No. 24.385 of January 14, 1976 / revoked by State Law No. 12.371/2005	14,242.05	Atlantic Forest Pampa	Porto Alegre, Canoas, Nova Santa Rita, Triunfo, Charqueadas and Eldorado do Sul
Espigão Alto State Park	State Decree No. 658/1949	1,331.9	Atlantic Forest	Barracão
Itapeva State Park	State Decree No. 42.009/2002.	998.06	Atlantic Forest	Torres
Itapuã State Park	State Decree No. 22.535/1973	5,566.50	Pampa	Viamão
Espinilho State Park	State Decree No. 23.798/1975	1,617.14	Pampa	Barra do Quaraí
Ibitiriá State Park	State Decree No. 23.798/1975	415	Atlantic Forest	Vacaria and Bom Jesus
Tainhas State Park	State Decree No. 23.798/1975	6,654.70	Atlantic Forest	Jaquirana, São Francisco de Paula and Cambará do Sul
Turvo State Park	State Decree No. 2.312/1947	17,491.40	Atlantic Forest	Derrubadas
Banhado dos Pachecos Wildlife Refuge	State Decree No. 41.559/2002	2,560	Pampa	Viamão
Serra Geral Biological Reserve	State Decree No. 30.788/1982.	4,845.76	Atlantic Forest	Maquiné, Terra de Areia and Itati
Aratinga Ecological Station	State Decree No. 37.345/1997	5,882	Atlantic Forest	São Francisco de Paula and Itati

Table 2. Five-level scale adapted from Faria (2004) to analyse and measure the effectiveness of management for 11 Conservation Units (CUs) of full protection in southern Brazil.

Score	Percentage ratio between optimal and current situation for the indicators (%)	Quality Standard
0	0–40	very poor or very unsatisfactory standard
1	41–55	less or unsatisfactory standard
2	56–70	average standard
3	71–85	high or satisfactory standard
4	86–100	standard of excellence or very satisfactory

Results

The 11 Conservation Units analysed in this study showed, in general, an intermediate standard in the classification of management effectiveness, with 18% of the studied CUs reaching a very unsatisfactory quality standard, 36% an unsatisfactory or average standard, 9% high or satisfactory and none with excellence level (Table 3). Considering the average of the scopes (56.9%), there is a trend of moderately satisfactory to lower or unsatisfactory, in relation to the quality standards of management effectiveness (Table 4) (Fig. 2).

Amongst the studied CUs, two showed a very unsatisfactory management quality standard with less than 40%: Espinilho State Park (PEESP) with 31.6% and Ibitiriá State Park (PEIB) with 39.6%. Four other CUs resulted in a low or unsatisfactory standard: Delta do Jacuí State Park (PEDJ) 45.2%, Itapeva State Park (PEVA) 54.5%, Espigão Alto State Park (PEA) 54.9% and Tainhas State Park (PETA) 55.6%. Four CUs were considered as average regarding the quality standard: Turvo State Park (PETU) 61.1%, Aratinga Ecological Station (EEA) 65.5%, Itapuã State Park (PEIT) 65.8% and Serra Geral Biological Reserve (REBIOSG) 66.6% (Fig. 2).

Only one of the 11 UCs reached a high or satisfactory quality standard, making up a total of 85.8%, Banhado dos Pachecos Wildlife Refuge (RVSBP) and none reached the excellence standard in management quality (Fig. 2). The eight scopes showed average mostly above 50% amongst the conservation units, which explains the variation between scopes (Fig. 3).

Table 3. Classification of the management effectiveness of the studied Conservation Units (CUs).

% Optimal total	Management quality standard	% total reached	evaluated CUs
up to 40%	Very unsatisfactory	18	2
41–55%	Unsatisfactory	36	4
56–70%	Average	36	4
71–85%	High or satisfactory	9	1
86–100%	Excellence	0	0

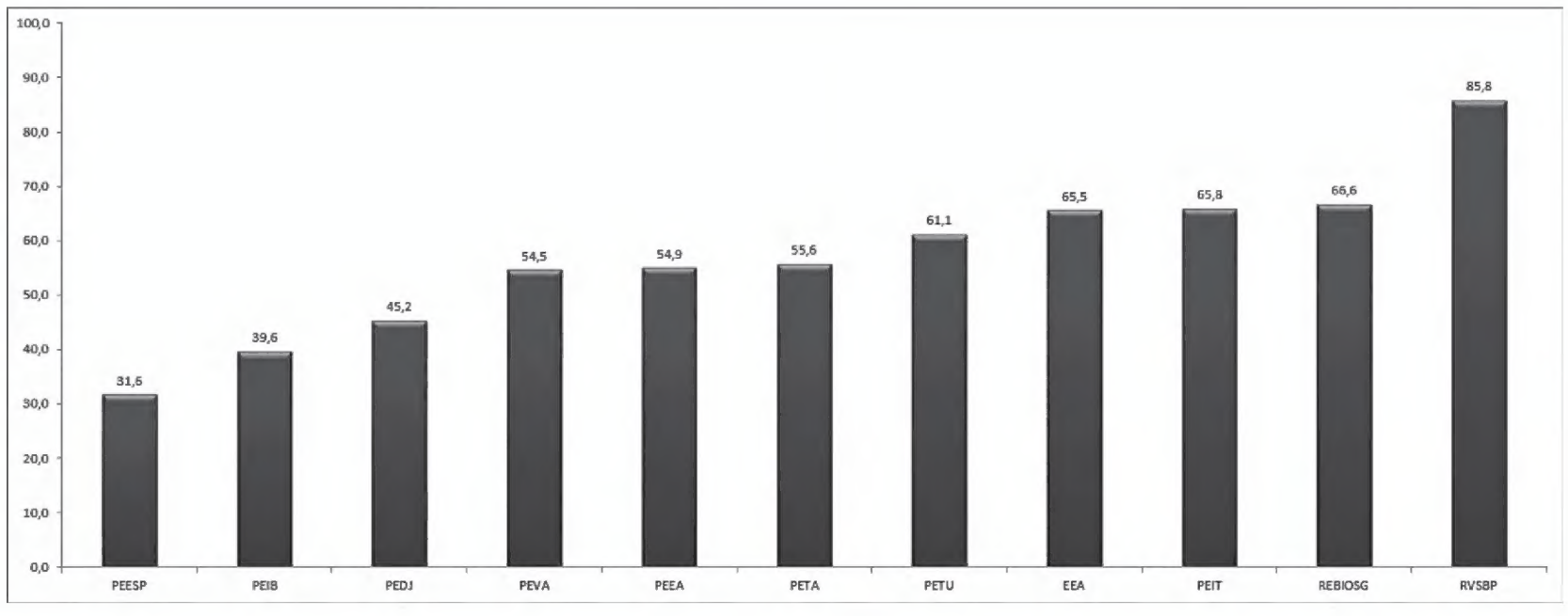

Figure 2. Average values of management effectiveness for each Conservation Unit analysed in southern Brazil, between March and July 2022. Conservation Units' acronyms: Ibitiriá State Park (PEIB); Delta do Jacuí State Park (PEDJ); Espigão Alto State Park (PEEA); Itapeva State Park (PEVA); Tainhas State Park (PETA); Turvo State Park (PETU); Itapuã State Park (PEIT); Aratinga Ecological Station (EEA); Serra Geral Biological Reserve (REBIOSG); and Banhado dos Pachecos Wildlife Refuge RVSBP.

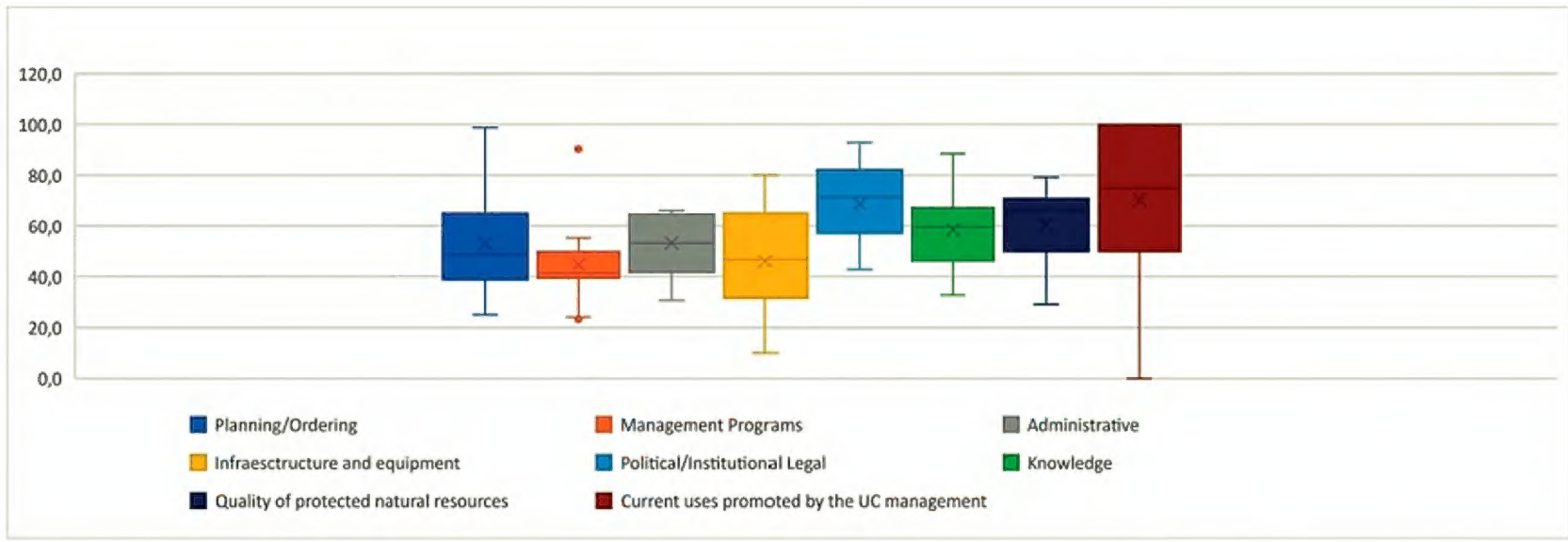

Figure 3. Boxplots expressing the general average of the eight scopes used in the analysis of Management Effectiveness for all 11 Conservation Units in southern Brazil, showing variations on average higher than 50%.

Table 4. Management effectiveness quality standard achieved (in percentages) by each conservation unit analysed in southern Brazil, between March and July 2022. Conservation Units' acronyms: Ibitiriá State Park (PEIB); Delta do Jacuí State Park (PEDJ); Espigão Alto State Park (PEEA); Itapeva State Park (PEVA); Tainhas State Park (PETA); Turvo State Park (PETU); Itapuã State Park (PEIT); Aratinga Ecological Station (EEA); Serra Geral Biological Reserve (REBIOSG); and Banhado dos Pachecos Wildlife Refuge RVSBP.

Scopes	PEIT	PETA	PEDJ	PEVA	PETU	PEIB	PEEA	PEESP	REBIOSG	RVSBP	EEA
Planning/Ordering	32.5	48.8	40.0	65.0	55.0	25.0	65.0	38.8	67.5	98.8	46.3
Management Programmes	55.3	50.0	24.2	43.1	41.4	23.3	41.4	39.4	44.4	90.3	39.6
Administrative	53.1	66.1	41.7	57.3	52.6	30.7	52.1	41.7	60.4	65.1	64.6
Infrastructure and equipment	75.0	53.3	31.7	31.7	65.0	23.3	31.7	10.0	46.7	80.0	58.3
Political/Institutional Legal	82.1	57.1	50.0	71.4	85.7	42.9	75.0	57.1	71.4	92.9	71.4
Knowledge	57.7	65.4	36.5	59.6	59.6	46.2	57.7	32.7	67.3	88.5	73.1
Quality of protected natural resources	70.8	29.2	62.5	58.3	79.2	50.0	66.7	33.3	75.0	70.8	70.8
Current uses promoted by the CU	100.0	75.0	75.0	50.0	50.0	75.0	50.0	0.0	100.0	100.0	100.0
Total	65.8	55.6	45.2	54.5	61.1	39.6	54.9	31.6	66.6	85.8	65.5

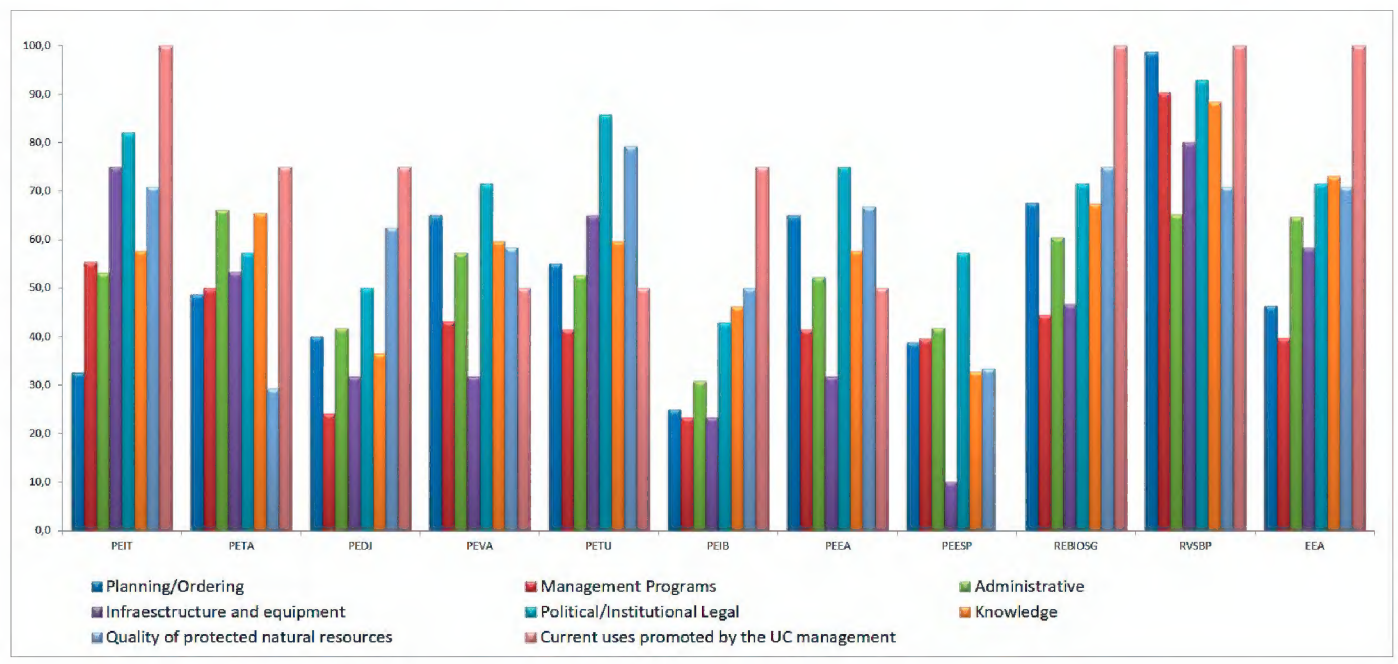

Figure 4. Results on the eight scopes analysed for each studied Conservation Unit in southern Brazil. Conservation Units' acronyms: Ibitiriá State Park (PEIB); Delta do Jacuí State Park (PEDJ); Espigão Alto State Park (PEEA); Itapeva State Park (PEVA); Tainhas State Park (PETA); Turvo State Park (PETU); Itapuã State Park (PEIT); Aratinga Ecological Station (EEA); Serra Geral Biological Reserve (REBIOSG); and Banhado dos Pachecos Wildlife Refuge RVSBP.

Considering the results, we identified the weak and strong points by scope for each CU studied (Fig. 4). A detailed description of these points by CU is presented in Suppl. material 2.

In the PCA of the Scope matrix (Table 5), only the first axis was significant in the randomisation test (p = 0.043) and considered for interpretation. This axis explained 63.8% of the matrix's total variation, having a strongly positive association (r ≥ 0.77) with all eight scopes considered, except for the quality of protected natural resources and for current uses promoted by the management of the CU, whose associations were also positive, but of moderate intensity (r ~ 0.6).

Therefore, this axis resulted from a common sign (+) between all scope variables and revealed a gradient of management quality standards between the CUs, with relatively low scores for Espinilho State Park (PEESP), Ibitiriá State Park (PEIB) and Delta do Jacuí State Park (PEDJ), medium scores for Espigão Alto State Park (PEEA), Itapeva State Park (PEVA) and Tainhas State Park (PETA), high scores for Turvo State Park (PETU), Itapuã State Park (PEIT), Aratinga Ecological Station (EEA) and Serra Geral Biological Reserve (REBIOSG) and very high scores for Banhado dos Pachecos Wildlife Refuge (RVSBP) (Fig. 5).

Furthermore, in the PCA of the matrix indicators (Table 6), only the first axis was significant in the Randomisation Test (p = 0.051), being retained for interpretation. This axis explained 37.5% of the total matrix variation, having a strongly positive association (r ≥ 0.67) with 18 indicators, moderately positive (r ≥ 0.43) with 13 indicators, weakly positive (r ≥ 0.13) with nine indicators and weakly (r ≤ -0.13) or moderately negative (r = -0.49) with the remaining three indicators. Thus, this axis represented a common sign (+) amongst the vast majority of the indicator variables and showed a gradient in the management quality standard between the CUs, with relatively low scores for Espinilho State Park (PEESP), Parque Estadual do Ibitiriá (PEIB) and Delta do Jacuí State Park (PEDJ), medium for Espigão Alto State Park (PEEA), Itapeva State Park (PEVA) and Tainhas State Park (PETA), high for Turvo State Park (PETU), Itapuã State Park (PEIT), Aratinga Ecological Station (EEA) and Serra Geral Biological Reserve (REBIOSG) and extremely high for Banhado dos Pachecos Wildlife Refuge (RVSBP).

Table 5. Principal Component Analysis with Randomisation Test for 11 Conservation Units in the State of Rio Grande do Sul, described by the correlation amongst eight general scopes of quality standard. Only the first three axes are shown.

Parameters	Axis 1	Axis 2	Axis 3
Eigenvalues	5.101	1.169	0.838
Percentage	63.8	14.6	10.5
P(roRnd ≥ ro)	0.043	0.49	0.36
Correlation (r) with original variables			
Planning/Ordering	0.76	-0.45	-0.21
Management Programmes	0.84	-0.38	0.08
Administrative	0.82	-0.22	0.29
Infrastructure and equipment	0.88	0.27	0.12
Political/Institutional Legal	0.87	-0.09	-0.41
Knowledge	0.94	-0.04	0.20
Quality of protected natural resources	0.59	0.55	-0.57
Current uses promoted by the CU management	0.62	0.63	0.40

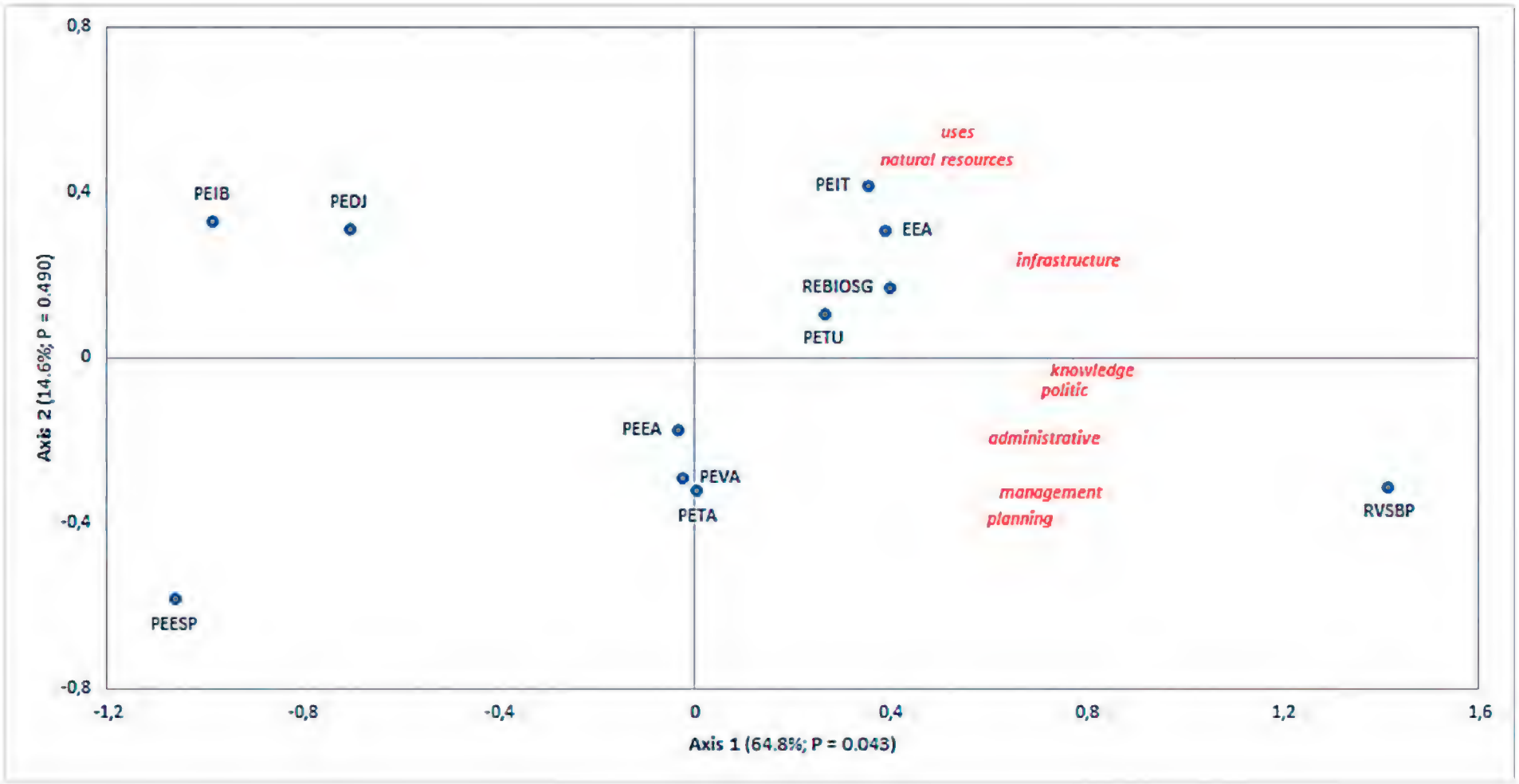

Figure 5. Principal Component Analysis with Randomisation Test for 11 State Conservation Units in Rio Grande do Sul, described by the correlation amongst eight scopes of management quality standard. Biplot of the first two axes, illustrating the dispersion of units and the association of areas with the axes. Only the variation in axis 1 (horizontal) was significant in the Randomisation Test ($P < 0.1$), being considered valid for interpretation. Conservation units' acronyms: Ibitiriá State Park (PEIB); Delta do Jacuí State Park (PEDJ); Espigão Alto State Park (PEEA); Itapeva State Park (PEVA); Tainhas State Park (PETA); Turvo State Park (PETU); Itapuã State Park (PEIT); Aratinga Ecological Station (EEA); Serra Geral Biological Reserve (REBIOSG); and Banhado dos Pachecos Wildlife Refuge (RVSBP). Scopes: planning and organisation; management programmes; administrative; infrastructure and equipment; political/institutional legal; knowledge; quality of protected natural resources; current uses promoted by management.

Table 6. Principal Component Analysis with Randomisation Test for 11 State Conservation Units in Rio Grande do Sul, described by the correlations amongst 43 management quality standard indicators. Only the first three axes are shown. Original variables are sorted in descending order of correlation (*r*) with axis 1.

Parameters	Axis 1	Axis 2	Axis 3
Eigenvalues	16.135	5.991	5.0322
Percentage	37.5	13.9	11.7
P(roRnd ≥ ro)	0.051	0.487	0.538
Correlation (r) with original variables			
Biophysical knowledge	0.97	0.13	-0.16
Limits and demarcation of the CU	0.89	0.02	-0.26
Application and compliance with standards	0.88	-0.01	0.35
Dynamics of organisation and planning	0.86	0.28	0.03
Gaps and/or biophysical supply	0.86	-0.16	-0.09
Consulting board	0.84	0.13	-0.01
Operations management programme	0.82	0.07	0.00
Disclosure of research studies – results	0.81	0.03	0.05
Infrastructure for research	0.80	0.11	0.11
Management plan	0.78	0.39	-0.29

Parameters	Axis 1	Axis 2	Axis 3
Public management programme	0.75	-0.17	-0.35
CU manager	0.74	-0.19	-0.53
Institutional support and human resources for research	0.74	-0.12	-0.19
Relationship and institutional support	0.71	-0.54	0.04
Research feedback	0.71	-0.52	-0.19
Agreements and partners for carrying out research	0.69	0.21	-0.04
Planning level	0.69	0.14	-0.25
Infrastructure and basic facilities	0.67	-0.42	0.19
Environmental zoning	0.64	0.19	0.24
Infrastructure for the execution of peculiar management programmes	0.64	-0.43	0.55
Staff	0.62	-0.58	0.20
Compatibility of uses	0.61	-0.04	-0.23
Percentage of altered areas within the CU	0.60	0.15	0.30
Interlocution system equipment	0.59	-0.10	0.11
Environmental management programme	0.59	-0.34	-0.57
Equipment and materials	0.58	0.54	0.46
Legal information	0.58	0.06	0.40
Current uses promoted by the management of the CU	0.48	-0.11	0.53
Springs and springs	0.48	0.57	0.26
Social support to CU	0.46	0.46	-0.08
Land situation	0.43	-0.24	-0.57
CU size	0.30	-0.07	0.81
Cartographic information gaps	0.24	0.86	0.31
Rules for scientific research	0.21	-0.31	-0.07
Cartographic information	0.19	0.59	0.47
Financial	0.19	0.16	0.23
CU form	0.16	0.63	0.01
Exploration of natural resources	0.16	-0.03	-0.55
Socioeconomic information	0.15	0.77	-0.39
Application of research results to the CU management	0.13	0.47	-0.39
Buffer zone	-0.04	0.33	-0.50
CU isolation/connectivity	-0.13	-0.58	0.55
Social conflicts	-0.49	0.57	-0.05

The indicators most directly associated with this gradient were, in decreasing order of relevance: biophysical knowledge (r = 0.97), limits and demarcation of the CU, application and compliance with norms, dynamics of organisation and planning, gaps and/or biophysical supply, advisory board, operations management programme, dissemination of research studies – results, research infrastructure and management plan (r = 0.78).

There was a moderate inverse association between Social Conflicts and the axis (r = -0.49), which indicates a commitment relationship between the axis and the indicators in general. In other words, CUs with better (worse) indicators, in general, had a moderate tendency to record more (less) aspects of social conflicts (Fig. 6). The legal political indicator was disregarded for this analysis because it did not vary between conservation units.

Figure 6. Principal Component Analysis with Randomisation Test for 11 State Conservation Units in Rio Grande do Sul, described by the correlations amongst 43 Management quality standard indicators. Biplot of the first two axes, illustrating the dispersion of units and the association of indicators with the axes. Only the variation in axis 1 (horizontal) was significant in the Randomisation Test ($p < 0.1$) and considered valid for interpretation. Conservation Units: Ibitiriá State Park (PEIB); Delta do Jacuí State Park (PEDJ); Espigão Alto State Park (PEEA); Itapeva State Park (PEVA); Tainhas State Park (PETA); Turvo State Park (PETU); Itapuã State Park (PEIT); Aratinga Ecological Station (EEA); Serra Geral Biological Reserve (REBIOSG); and Banhado dos Pachecos Wildlife Refuge (RVSBP).

Discussion

In this study, 11 CUs from the 23 existing in the State of Rio Grande do Sul were assessed and all have significant ecological importance for biodiversity conservation and maintenance of ecological processes, mainly because they are located in biomes of extreme relevance for Brazilian territory: Pampa and Atlantic Forest biomes. However, in general, the management effectiveness of these areas varied from average to low levels of conservation success, according to the EMAP method. Moreover, they did not fulfil the ideal objectives for which they were established. The scopes and indicators used for evaluation in this study involved the main elements for the management of a protected area, which are basic for its fulfilment and are based, above all, on the elements that make up the management plans. The application of the EMAP method

demonstrated that it is an important instrument to evaluate and monitor management effectiveness and can be applied by the managers of the CUs once they have been trained. Our results can be used by managers to improve management actions and achieve assertive goals for the efficiency of their conservation units. In this context, the adoption of evaluation mechanisms for management effectiveness is the first step amongst other actions for the successful management of protected areas.

In this study, 91% of the CUs assessed in southern Brazil by the EMAP method oscillated from average to very unsatisfactory efficacy and low management effectiveness (Table 3). Most of these units only had the basic means necessary to develop essential management programmes to achieve their goals. This scenario with similar results was also observed by Lima et al. (2005) for Minas Gerais CUs and by Faria (2006) for São Paulo State CUs. Lima et al. (2005), in the State of Minas Gerais, using the EMAP methodology, evaluated the management effectiveness of 39 state and national integral protection CUs. They concluded that 23 units (60%) from Minas Gerais showed an unsatisfactory level of management, with only one showing a satisfactory level. In 87% of the CUs, there were no management plans and no type of management planning was adopted (Lima et al. 2005). Although the results have pointed out several deficiencies in management, similar to other studies (Faria 2006; Santos 2016; Carvalho 2020; Wenceslau 2020), amongst other authors, the evaluation carried out by Lima et al. (2005), did not consider the existence of the main management instrument for protected areas, such as having a "Management Plan" as a criterion for choosing units.

Faria (2006), when evaluating the management effectiveness of 41 CUs in the State of São Paulo, also by the EMAP method, found that 88% had an average to unsatisfactory quality standard and only five (12%) had a satisfactory standard. It was observed that most of the units studied herein had the basic means necessary to develop essential management programmes to achieve their goals, but showed low management effectiveness, the same observed by Faria (2006).

A deficiency observed in terms of management procedures, such as systematic environmental monitoring, updated management plan, frequent maintenance of headquarters, implementation of consultative councils etc., prevents the effective fulfilment of the proposed objectives for the conservation of most of the protected areas analysed herein. A general suggestion for almost all CUs analysed is the establishment of flows and the administrative conduct needs to be reviewed in terms of the model used. This is corroborated by the opinion of the CU managers, according to whom the solutions must come from the managing body to establish a standardised management model (Lima et al. 2005; Silveira et al. 2012; Pegler 2018).

It is worth mentioning that the EMAP method, although extremely adaptable, is based on indicators that permeate the "management plan", such as zoning, management programmes, research, inspection, infrastructure, economic situation, amongst other related aspects. The EMAP method is adaptable, as long as the methodological principles are maintained and allows the creation of current scenarios, having a compatible numerical valuation scale (Likert 1932) assigned to several indicators applied in our study. In this way, we measured the current situation of each CU. The adaptation of new scenarios to the reality of the CUs enabled the analysis of evaluation and future projections, establishing

between researcher and manager the possibility of analysing and building a dynamic model of reality.

The management plans evaluated in this study are mostly outdated, as is the case of the Itapuã State Park, published in 1996 and, for the other CUs, the plans were published in the 2000s, more than 20 years ago. Management activities related to the CUs' outdated management plans, for the most part, are being supplied through adaptations of secondary operation plans to meet the basic objectives, such as supervision. Moreover, although all CUs analysed in this paper have management plans, some have several deficiencies, such as the lack of financial resources and staff, precarious infrastructure or no structure and lack of land regularisation.

The lack of attention to these points prevents the effective fulfilment of the objectives, with the role of the managing body in the organisational structure of the CUs. Similar results were also found by Carvalho (2020) in eight integral protection units in the Republic of Cape Verde in Africa. They found a deficiency on the part of the management body regarding the establishment of tools for the preparation of technical management documents to provide better planning with clear and standardised guidelines through a model, in a dynamic way, following the evolution of management processes.

Another relevant aspect is the lack of standardisation in the elaboration and implementation processes, which was also observed by Santos (2016) in State Parks of Minas Gerais. Rodrigues (2014) also concluded the absence of standardisation in the management processes of those areas when analysing the management of four integral protection units in the State of Tocantins in Brazil using the Management Excellence Model (MEG method) when investigating the management maturity of the areas. Many deficiencies were observed in the management processes and only one of the four presented a high level of management quality. The author also related the low performance to the lack of standardisation of the management processes and believed that is linked to a managerial culture.

The creation of advisory councils for the units is also an issue that needs to be highlighted. We found in our study that, in some cases, the elaboration of management plans preceded the establishment of councils, which are of paramount importance for the legitimacy of management actions. These councils have the equal participation of representatives of governmental and non-governmental civil society, which is a very important aspect of CU management (Carvalho 2020). Amongst the areas analysed herein, three parks lacked advisory councils: Delta do Jacuí State Park, Espinilho State Park and Ibitiriá State Park, probably resulting in loss of management efficiency.

The scopes evaluated through the application of multiple regression, which in general pointed to a higher standard of quality of management effectiveness (EFG), were the scopes: political legal, current uses promoted by the management and quality of natural resources. The political-legal scope, within this set of indicators, presented 68.8% of effectiveness, which consists of framing the CU and its legal norms. All areas studied have their legal instruments of creation. Although the managing bodies of many CUs are not the legal owners of the land, they are responsible for its use and can protect the environmental attributes in some way.

Faria (2006) evaluated CUs from the São Paulo State (SP) and found similar results to those of the present study, mainly concerning the land situation be-

cause, although the score was high in SP, the land regularisation of the areas needs to be carried out by the State government and its Department of Environment, like in southern Brazil. Moreover, the existence of a decree creating the conservation unit was also an indicator with a high overall score for both States, SP and RS, because all CUs have such a decree. However, in both cases, CUs created before Brazilian Federal Law 9.985 need to be revised because not all areas were acquired by the State government and some cases remain as private property.

Another scope that resulted in the second highest relevance was that of current uses promoted by the manager. In most units, managers promote uses compatible with the goals of the management categories, totalling 65.9% of effectiveness. The quality of protected natural resources was the third most important, with a management efficiency of 60.6%. According to Faria (2006), this scope added little to explain the model.

Our results indicated that all studied units urgently need more human and financial resources (for details for each CU, see Suppl. material 2). We also recommend the adoption of a quali-quantitative evaluation model for the units (through a mathematical model) to periodically measure their own management efficiency. However, each CU analysed has its own idiosyncrasies.

In this context, we made the following specific recommendations for each CU for improving the management effectiveness based on their weak and strong points (see, Suppl. material 2):

The Espinilho State Park needs improvements in its physical structures to meet the promotion of public use, environmental education and activities of scientific research to reach its goals. Moreover, it is recommended that there should be more employees to manage the area, mainly due to the hunting pressure and the need to monitor the buffer zone, which has a predominance of crops and cattle raising. It is also suggested the acquisition of materials and equipment.

For the Ibitiriá State Park, the most important recommendations are its land regularisation, removal of liabilities from the interior of the CU and the construction of infrastructure to accommodate the manager and staff.

The Delta do Jacuí State Park needs to create its consultative council and implement management programmes, besides improving its infrastructure and acquiring equipment. Scientific research must be encouraged. This CU needs financial improvement for its administration.

Regarding the Tainhas State Park, its effective land tenure regularisation is essential, as well as the elimination of liabilities that threaten the conservation of the area. Moreover, it is necessary to increase the number of personnel. It is also recommended that attention should be given to the buffer zone, which has extensive areas of invasive exotic species, with monoculture cultivation and cattle raising.

The Espigão Alto State Park needs to carry out land regularisation and increase its staff, equipment and infrastructure (such as accommodation, machines) to improve management and research activities. It is also important to ratify and implement its revised management plan. It is recommended to monitor the buffer zone due to the extensive production areas with invasive alien species on its borders.

For the Itapeva State Park, is recommended to improve land regularisation and the staff size, especially rangers, implement infrastructure and allocate equipment for activities in the park area. The revised management plan needs

to be approved and its management programmes must be implemented. The zoning activity deserves attention, due to local conflicts with the urban expansion of the city.

Concerning the Itapuã State Park, it is recommended to update its management plan, increase the staff size and improve the maintenance of its infrastructure, mainly the administrative buildings and accommodation for researchers. Another point that deserves attention is the presence of hunting and fishing in the CU because it is accessible via water.

For the Turvo State Park it is recommended that there be an increase in the number of employees and an improvement in the accommodation for researchers. The surveillance deserves attention due to the presence of illegal hunting and illicit trafficking through the border area, which is accessible via water. Another point of concern refers to the monitoring of the buffer zone, which showed inadequate land use with extensive areas bordering the CU having invasive exotic species and the use of pesticides that drain into water sources.

For the Aratinga Ecological Station, it is recommended that there should be land tenure regularisation in the protected area and the removal of liabilities, as well as the increase in the number of staff members. It is also important to build an infrastructure in the CU to receive the staff and the administrative personnel. The existence of invasive and exotic species of flora and fauna in the CU, as well as conflicts with hunters and fishermen, are points of attention.

Regarding the Serra Geral Biological Reserve, it is recommended to increase the number of staff members (park rangers and technical/administrative personnel). It is also important to implement infrastructure, mainly in the headquarters, with equipment and technological support. There are some points of attention about monitoring the buffer zone, which has conflicts with hunting, records of pesticide use in the surrounding plantations and exotic species occurring in the CU.

For the Banhado dos Pachecos Wildlife Refuge, it is recommended to increase staff members, the acquisition of materials and equipment, improvements in existing infrastructure and basic facilities for administration, inspection, education and research (accommodation). It is also worth highlighting the existence of hunting activity in its surroundings mainly due to the presence of the Pantanal deer, amongst other species, in this CU.

Finally, several previous studies supported the result that the creation of CUs is not enough to meet the goals set for biodiversity conservation (see, for example, Cifuentes et al. (2000); Faria (2006); Carvalho (2020)), mainly due to lack of human and economic resources that affect the efficiency of the management in protected areas. Although the National System of Nature Conservation Units (SNCU) allows private and citizen donors in general, this is not a common or current practice in Brazil, which should be encouraged as an alternative to help the management in protected areas.

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Additional information

Conflict of interest

The authors have declared that no competing interests exist.

Ethical statement

No ethical statement was reported.

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Author contributions

P.B.R.W., H.H.F. and L.R.O. developed the conceptualization of the study. P.B.R.W, H.H.F.,. designed the experiments. P.B.R.W carried out the interviews in the CUs. P.B.R.W. and J.M.O. performed the formal analysis. L.R.O. were responsible for acquiring funds P.B.R.W and L.R.O. administering the project. P.B.R.W. and L.R.O. wrote the original draft. P.B.R.W., H.H.F., L.R.O. and J.M.O. revised and edited the final version of the manuscript.

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Data availability

All of the data that support the findings of this study are available in the main text or Supplementary Information.

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Supplementary material 1

Parameters to evaluate the Effectiveness of Management of Protected Areas (EMAP) applied to eleven conservation units

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Data type: docx

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Supplementary material 2

Detailed description of the evaluated conservation units, with the identification of their weak and strong points

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Data type: docx

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